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PATENT SPECIFICATION

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PROVISIONAL SPECIFICATION

Improvements in and relating to Folded Dipole Aerials

... to Figures 1 and 2, comprising two con-

SPECIFICATION NO. 652716

INVENTORS:- ARTHUR HENRY ASHFORD WYNN and JOHN KENNETH OXENHAM

By a direction given under Section 17(1) of the Patents Act 1949 this application proceeded in the name of A. C. Cossor Limited, a British Company, of Cossor House, Highbury Grove, London, N.5.

THE PATENT OFFICE,
2nd July, 1951

DS 86551/1(5)/3550 160 6/51 R

...anying ... comprises two conductors 10 and 11, each of a length equal to substantially a quarter of the wavelength at which the aerial is to be operated, having their adjacent ends connected to terminals E and F, these terminals constituting input terminals in the case of a transmitting aerial and output terminals in the case of a receiving aerial. The structure 10, 11 thus constitutes a normal dipole aerial system of length $\lambda/2$, where λ is the wavelength. In a folded dipole a further conductor 12 is provided parallel to the conductors 10 and 11 and close to them, the outer ends G and H of the dipole being connected to the outer ends G^1 and H^1 of the further conductor 12.

In one form of folded dipole that has become known, the ends G, G^1 and H, H^1 are brought into close proximity with one another as shown in Figure 2, the aerial structure thus being given an annular form. In order that the conductors 10, 11 on the one hand and 12 on the other hand may be visible in Figure 2, they are shown somewhat displaced from one another. In practice, they are disposed one above the other. In the known arrangement, a condenser 13 is connected between the adjacent ends G and H.

The folded dipole aerial structure with which the present invention is concerned is of the type which will be understood from the description given with reference ...

The present invention has for one of its objects to provide an aerial structure of the type set forth which whilst efficient in operation is simple and cheap to construct.

A further object of the invention is to provide an aerial structure of the type set forth which for any given wavelength can be made of smaller size than known dipoles of this type.

According to the present invention, in an aerial structure of the type set forth, the conductors constituting the centre-fed dipole and the said further conductor or conductors are arranged on opposite sides of an insulating member and the conductors are in the form of thin strips of conducting material carried by the insulating member.

The insulating member may be in the form of a flat plate and the conductors may be applied on the two sides of the plate in any convenient way; for example by a printing process; by spraying through a suitable mask; by sputtering; or by providing the insulating support with recesses according to a desired pattern, coating the whole of the surfaces, including the recesses, with metal by spraying, sputtering or otherwise, and then removing the raised portions of the support and the metal coating thereon by grinding or otherwise, thus leaving conductors of the desired shape, as defined

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Index at acceptance:—Class 40(vii), AE(3m : 4a5), AE6(c : d : fx : s).

PROVISIONAL SPECIFICATION

Improvements in and relating to Folded Dipole Aerials

We, A. C. Cossor Limited, of Cossor House, Highbury Grove, London, N.5, a British Company, and Arthur Henry Ashford Wynn and John Kenneth Oxenham, both of the Company's address and both British subjects, do hereby declare the nature of this invention to be as follows:—

The present invention relates to folded dipole aerials.

As shown in Figure 1 of the accompanying drawing, a folded dipole aerial comprises two conductors 10 and 11, each of a length equal to substantially a quarter of the wavelength at which the aerial is to be operated, having their adjacent ends connected to terminals E and F, these terminals constituting input terminals in the case of a transmitting aerial and output terminals in the case of a receiving aerial. The structure 10, 11 thus constitutes a normal dipole aerial system of length $\lambda/2$, where λ is the wavelength. In a folded dipole a further conductor 12 is provided parallel to the conductors 10 and 11 and close to them, the outer ends G and H of the dipole being connected to the outer ends G^1 and H^1 of the further conductor 12.

In one form of folded dipole that has become known, the ends G, G^1 and H, H^1 are brought into close proximity with one another as shown in Figure 2, the aerial structure thus being given an annular form. In order that the conductors 10, 11 on the one hand and 12 on the other hand may be visible in Figure 2, they are shown somewhat displaced from one another. In practice, they are disposed one above the other. In the known arrangement, a condenser 13 is connected between the adjacent ends G and H.

The folded dipole aerial structure with which the present invention is concerned is of the type which will be understood from the description given with reference to Figures 1 and 2, comprising two conductors arranged with their adjacent ends connected to input or output terminals to form a centre-fed dipole, a further conductor or conductors disposed alongside the said two conductors and connections between points at or near the ends of the dipole remote from the said terminals and points at or near the ends of the said further conductor or conductors respectively, the structure having a pari-annular form. The annulus may be of circular, square or other shape.

The present invention has for one of its objects to provide an aerial structure of the type set forth which whilst efficient in operation is simple and cheap to construct.

A further object of the invention is to provide an aerial structure of the type set forth which for any given wavelength can be made of smaller size than known dipoles of this type.

According to the present invention, in an aerial structure of the type set forth, the conductors constituting the centre-fed dipole and the said further conductor or conductors are arranged on opposite sides of an insulating member and the conductors are in the form of thin strips of conducting material carried by the insulating member.

The insulating member may be in the form of a flat plate and the conductors may be applied on the two sides of the plate in any convenient way; for example by a printing process; by spraying through a suitable mask; by sputtering; or by providing the insulating support with recesses according to a desired pattern, coating the whole of the surfaces, including the recesses, with metal by spraying, sputtering or otherwise, and then removing the raised portions of the support and the metal coating thereon by grinding or otherwise, thus leaving conductors of the desired shape, as defined

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by the recesses, on the two sides of the plate. The conductors may, for example, be applied by one of the methods described in the Specification of co-pending Patent Application No. 9022/48 (Serial No. 652,398).

The invention will be described by way of example with reference to other Figures of the accompanying drawings in which Figures 3 and 4 are diagrammatic views in plan and under-side plan, respectively, of one embodiment, Figure 5 contains curves illustrating one aspect of the invention, Figures 6 and 7 are views of the two sides of a further aerial structure according to the invention, Figures 8, 9 and 10 are diagrammatic plan views showing the shapes of the conductors used in a three-layer aerial structure according to the invention and Figure 11 is a diagrammatic view in cross-section on the line Z—Z of Figures 8, 9 and 10.

In all the Figures representing embodiments, four corners of a square insulating plate 14 serving as support for the conductors of the aerial system are represented by A, B, C and D. The conductors themselves in the form of thin strips produced in one of the ways referred to are shown shaded.

Referring to Figures 3 and 4, input or output terminals are, as in Figures 1 and 2, represented by the letters E and F. Points such as J and K on the conductors on the upper surface of the support are connected by rivets or the like passing through the support to points such as J^1 and K^1 respectively on the under-surface. The path of a direct current between points E and F would therefore be from E to J, J to J^1, J^1 to K^1, K^1 to K, and K to F. The conductor on the under-surface of the support is in this example made broader than that on the upper surface. This can be shown to increase the input resistance of the aerial structure measured between terminals E and F. For many purposes this is desirable, but the employment of conductors of different widths either to increase or decrease the input resistance is not an essential feature of the invention. The support 14 is made of suitable dielectric material of low loss, such for example as polystyrene.

For the purpose of explaining the operation of the arrangement of Figures 3 and 4, reference will again be made to the plain folded dipole shown in Figure 1. It is known that the aerial presents a purely resistive impedance across the terminals EF, and is therefore resonant at a frequency for which its length GH or G^1H^1 is approximately equal to half a wavelength. This resonance may be considered as the combination of two separate resonance modes; one being that of a simple dipole consisting of the elements GEFH and G^1H^1 radiating in parallel, and the other that of a pair of short-circuited quarter-wave stubs, formed by sections FHH^1M and EGG^1M in series. It will be appreciated that the component of current at EF due to the latter mode is negligible, and as the two rods radiating in parallel act as a single rod of larger diameter (i.e. as an ordinary half-wave dipole) the resultant input impedance is resistive.

If the space between the elements GEFH and G^1MH^1 is filled with some dielectric substance, the resonance frequency of the rods radiating in parallel remains unaltered, but the electrical length of the stubs is changed. It is therefore seen that the insertion of dielectric will introduce a reactive component in the impedance across the terminals EF. If, however, the stubs are suitably shortened by connecting the elements together at points JJ^1 and KK^1 so that their combined electrical length is equal to a half-wavelength in the dielectric, or an integral multiple thereof, the impedance of the aerial can again be made resistive. Similarly, if the dipole has a length other than that of half a wavelength, so that the elements radiating in parallel have a reactive component, the aerial may be returned to a resonant condition by choosing a suitable stub length. With an interposed dielectric it will normally be found that the physical length of the stub will require to be less than the total aerial length, and that in the limiting condition in which the physical lengths of the dipole and stubs are equal, these lengths can be made smaller as the permittivity of the dielectric is increased.

It will be appreciated that when a folded dipole in an air medium, or having its elements separated by some dielectric substance, is bent round into the form of a loop, the resonance frequency will change owing to the altered coupling between the various elements. This modification complicates the calculation of any specific example, and for this reason a graphical method of solution is preferred.

By way of example, the embodiment shown in Figures 3 and 4, in which the points JJ^1 and KK^1 are connected together through the dielectric base by means of copper rivets or the like, will be considered with reference to the curves shown in Figure 5, in which the abscissa represents the frequency f of oscillations applied to the input terminals EF in Figures 3 and 4. It is assumed that the

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relevant dimensions are known and that the permittivity of the dielectric base is relatively low, not differing greatly from unity, and that it is required to determine the frequencies for which the aerial presents a purely resistive impedance at the terminals EF. For the present purpose, the aerial structure is regarded as composed of two parts, as was the simple folded dipole shown in Figure 1; the first part consisting of the radiators in parallel (equivalent to a simple dipole) and the second of a pair of stubs, one stub being constituted by the conductor from E to J and J^1 to M, and the other by the conductor F to K and K^1 to M. In Figure 5, the full line curve AS relating susceptance and frequency, and the chain dotted line curve RC relating conductance and frequency refer to the part consisting of the parallel radiators, while the broken line SS represents the combined susceptance of the two stubs plotted against frequency. f_r is the frequency at which the parallel radiators resonate, and f_s the frequency at which the stubs have electrical lengths which, when added together, are equal to half a wavelength (or an integral multiple thereof) in the dielectric. It is seen that at a frequency f_1 the susceptance of the parallel radiators substantially balances the stub susceptance, and consequently the desired condition of zero reactance is obtained; the remaining resistive component being the reciprocal of the conductance indicated by the curve RC at this frequency. Another frequency at which balance can be obtained is indicated by f_2. There will also be a sequence of higher frequencies (not shown) at which further balances may be obtained, but these will not normally be of any interest. In Figure 5 the permittivity was assumed to be small; higher values increase the electrical lengths of the stubs and thereby lower the stub resonance frequency. In this way it may be possible to find more than one frequency below f_r at which the susceptances balance, leaving the impedance of the aerial purely resistive.

It should be noted that it is not necessary to have JJ^1 and KK^1 symmetrically disposed, as long as the value of susceptance at the required frequency (usually f_1) is unaltered. In particular, either or both of the points JJ^1 and KK^1 may coincide with the ends GG^1 and HH^1.

It will be appreciated that in all cases the frequency f_1 can be made substantially less than the parallel resonance frequency f_r, or in other words, at a given frequency an aerial constructed in accordance with this invention can be made of smaller dimensions than a normal half-wave dipole.

In the form of the invention illustrated in Figures 3 and 4, a singly folded dipole is used. Figures 6 and 7 show one way in which a doubly folded dipole may be produced in accordance with the invention. The conductor on the front surface of the support 14 is, as shown in Figure 6, of the same form as that in Figure 3. On the back surface of the support 14 are provided two conductors, one within the other and insulated from one another excepting at the ends G^1 and H^1. These ends G^1 and H^1 or other suitable points are connected by rivets or the like to the points G and H or other points respectively in Figure 6.

Another way in which multi-folded dipoles can be produced is by employing a plurality of supports. One example where the folding is double is shown in Figures 8, 9, 10 and 11. The structure comprises two insulating supports 14^1 and 14^{11}, the former having a conductor 15 of the shape shown in Figure 8 arranged on its upper surface and no conductor upon its lower surface. The supporting member 14^{11}, shown in Figure 9, has conductors 16 and 17 of the shape shown arranged upon its upper surface and thus in contact with the lower surface of the supporting member 14^1 and a conductor 18 as shown in Figure 10 upon its lower surface. Suitable points such as H and H^1 and G and G^1 are connected together respectively, while the ends P and Q are left unconnected.

The reactance between terminals E and F may be neutralised by suitably choosing the points to be connected together as already described with reference to Figures 3 and 4.

Dated this 21st day of September, 1948.

REDDIE & GROSE,

Agents for the Applicants,

6, Bream's Buildings, London, E.C.4.

COMPLETE SPECIFICATION

Improvements in and relating to Folded Dipole Aerials

We, A. C. COSSOR LIMITED, of Cossor House, Highbury Grove, London, N.5, a British Company, and ARTHUR HENRY ASHFORD WYNN and JOHN KENNETH OXENHAM, both of the Company's address and both British subjects, do hereby declare the nature of this invention, and in what manner the same is to

be performed, to be particularly described and ascertained in and by the following statement:—

The present invention relates to folded dipole aerials.

As shown in Figure 1 of the drawings accompanying the Provisional Specification, a folded dipole aerial comprises two conductors 10 and 11, each of a length equal to substantially a quarter of the wavelength at which the aerial is to be operated, having their adjacent ends connected to terminals E and F, these terminals constituting input terminals in the case of a transmitting aerial and output terminals in the case of a receiving aerial. The structure 10, 11 thus constitutes a normal dipole aerial system of length $\lambda/2$, where λ is the wavelength. In a folded dipole a further conductor 12 is provided parallel to the conductors 10 and 11 and close to them, the outer ends G and H of the dipole being connected to the outer ends G^1 and H^1 of the further conductor 12.

In one form of folded dipole that has become known, the ends G, G^1 and H, H^1 are brought into close proximity with one another as shown in Figure 2 the aerial structure thus being given an annular form. In order that the conductors 10, 11 on the one hand and 12 on the other hand may be visible in Figure 2, they are shown somewhat displaced from one another. In practice, they are disposed one above the other. In the known arrangement, a condenser 13 is connected between the adjacent ends G and H.

The folded dipole aerial structure with which the present invention is concerned is of the type, which will be understood from the description given with reference to Figures 1 and 2, comprising two conductors arranged with their adjacent ends connected to input or output terminals to form a centre-fed dipole, a further conductor or conductors disposed alongside the said two conductors and connections between points at or near the ends of the dipole remote from the said terminals and points at or near the ends of the said further conductor or conductors respectively, the structure having a part-annular form. The annulus may be of circular, square or other shape.

The present invention has for one of its objects to provide an aerial structure of the type set forth which whilst efficient in operation is simple and cheap to construct.

A further object of the invention is to provide an aerial structure of the type set forth which for any given wavelength can be made of smaller size than known dipoles of this type.

According to the present invention, in an aerial structure of the type set forth, the conductors constituting the centre-fed dipole and the said further conductor or conductors are arranged on opposite sides of an insulating member and the conductors are in the form of thin strips of conducting material carried by the insulating member.

Further according to this invention there is provided an aerial structure of the type set forth comprising three or more sets of conductors one of which constitutes the centre-fed dipole and the other sets constituting the said further conductors, and a plurality of insulating members arranged in a stack, two of the sets being disposed upon the two outer surfaces of the stack and the one or more other sets being disposed between adjacent insulating members.

The insulating member or each of such members may be in the form of a flat plate and the conductors may be applied on the two sides of the plate in any convenient way; for example by a printing process; by spraying through a suitable mask; by sputtering; or by providing the insulating support with recesses according to a desired pattern, coating the whole of the surfaces, including the recesses, with metal by spraying, sputtering or otherwise, and then removing the raised portions of the support and the metal coating thereon by grinding or otherwise thus leaving conductors of the desired shapes, as defined by the recesses, on the two sides of the plate. The conductors may, for example, be applied by one of the methods described in the specification of co-pending Patent Application No. 9022/84 (Serial No. 652,398).

The invention will be described by way of example with reference to other Figures of the drawings accompanying the Provisional Specification in which Figures 3 and 4 are diagrammatic views in plan and under-side plan, respectively, of one embodiment, Figure 5 contains curves illustrating one aspect of the invention, Figures 6 and 7 are views of the two sides of a further aerial structure according to the invention, Figures 8, 9 and 10 are diagrammatic plan views showing the shapes of the conductors used in a three-layer aerial structure according to the invention, Figures 8, 9 and 10 are diagrammatic plan views showing the shapes of the conductors used in a three-layer aerial structure according to the invention and Figure 11 is a diagrammatic view in cross-section on the line x—x of Figures 8, 9, and 10.

In all the Figures representing embodi-

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ments, four corners of a square insulating plate 14 serving as support for the conductors of the aerial system are represented by A, B, C and D. The conductors themselves in the form of thin strips produced in one of the ways referred to are shown shaded.

Referring to Figures 3 and 4, input or output terminals are, as in Figures 1 and 2, represented by the letters E and F. Points such as J and K on the conductors on the upper surface of the support are connected by rivets or the like passing through the support to points such as J^1 and K^1 respectively on the under-surface. The path of a direct current between points E and F would therefore be from E to J, J to J^1, J^1 to K^1, K^1 to K, and K to F. The conductor on the under-surface of the support is in this example made broader than that on the upper surface. This can be shown to increase the input resistance of the aerial structure measured between terminals E and F. For many purposes this is desirable, but the employment of conductors of different widths either to increase or decrease the input resistance is not an essential feature of the invention. The support 14 is made of suitable dielectric material of low loss, such for example as polystyrene.

For the purpose of explaining the operation of the arrangement of Figures 3 and 4, reference will again be made to the plain folded dipole shown in Figure 1. It is known that the aerial presents a purely resistive impedance across the terminals EF, and is therefore resonant, at a frequency for which its length GH or G^1H^1 is approximately equal to half a wavelength. This resonance may be considered as the combination of two separate resonance modes; one being that of a simple dipole consisting of the elements GEFH and G^1H^1 radiating in parallel, and the other that of a pair of short-circuited quarter-wave stubs, formed by sections FHH^1M and EGG^1M in series. It will be appreciated that the component of current at EF due to the latter mode is negligible, and as the two rods radiating in parallel act as a single rod of larger diameter (i.e. as an ordinary half-wave dipole) the resultant input impedance is resistive.

If the space between the elements GEFH and G^1MH^1 is filled with some dielectric substance, the resonance frequency of the rods radiating in parallel remains unaltered, but the electrical length of the stubs is changed. It is therefore seen that the insertion of dielectric will introduce a reactive component in the impedance across the terminals EF. If, however, the stubs are suitably shortened by connecting the elements together at points JJ^1 and KK^1 so that their combined electrical length is equal to a half-wavelength in the dielectric, or an integral multiple thereof, the impedance of the aerial can again be made resistive. Similarly, if the dipole has a length other than that of half a wavelength, so that the elements radiating in parallel have a reactive component, the aerial may be returned to a resonant condition by choosing a suitable stub length. With an interposed dielectric it will normally be found that the physical length of the stub will require to be less than the total aerial length, and that in the limiting condition in which the physical lengths of the dipole and stubs are equal, these lengths can be made smaller as the permittivity of the dielectric is increased.

It will be appreciated that when a folded dipole in an air medium, or having its elements separated by some dielectric substance, is bent round into the form of a loop, the resonance frequency will change owing to the altered coupling between the various elements. This modification complicates the calculation of any specific example, and for this reason a graphical method of solution is preferred.

By way of example, the embodiment shown in Figures 3 and 4, in which the points JJ^1 and KK^1 are connected together, through the dielectric base by means of copper rivets or the like, will be considered with reference to the curves shown in Figure 5, in which the abscissa represents the frequency f of oscillations applied to the input terminals EF in Figures 3 and 4. It is assumed that the relevant dimensions are known and that the permittivity of the dielectric base is relatively low, not differing greatly from unity, and that it is required to determine the frequencies for which the aerial presents a purely resistive impedance at the terminals EF. For the present purpose, the aerial structure is regarded as composed of two parts, as was the simple folded dipole shown in Figure 1; the first part consisting of the radiators in parallel (equivalent to a simple dipole) and the second of a pair of stubs, one stub being constituted by the conductor from E to J and J^1 to M, and the other by the conductor F to K and K^1 to M. In Figure 5, the full line curve AS relating susceptance and frequency, and the chain dotted line curve RC relating to conductance and frequency refer to the part consisting of the parallel radiators, while the broken line SS represents the combined susceptance of the two stubs plotted against frequency. f_r is the frequency at which the parallel radiators resonate, and

f_s the frequency at which the stubs have electrical lengths which, when added together, are equal to half a wavelength (or integral multiple thereof) in the dielectric. It is seen that at a frequency f_1 the susceptance of the parallel radiators substantially balances the stub susceptance, and consequently the desired condition of zero reactance is obtained; the remaining resistive component being the reciprocal of the conductance indicated by the curve RC at this frequency. Another frequency at which balance can be obtained is indicated by f_2. There will also be a sequence of higher frequencies (not shown) at which further balances may be obtained, but these will not normally be of any interest. In Figure 5 the permittivity was assumed to be small; higher values increase the electrical lengths of the stubs and thereby lower the stub resonance frequency. In this way it may be possible to find more than one frequency below f_r at which the susceptance balance, leaving the impedance of the aerial purely resistive.

It should be noted that it is not necessary to have JJ^1 and KK^1 symmetrically disposed, as long as the value of susceptance at the required frequency (usually f_1) is unaltered. In particular, either or both of the points JJ^1 and KK^1 may coincide with the ends GG^1 and HH^1.

It will be appreciated that in all cases the frequency f_1 can be made substantially less than the parallel resonance frequency f_r, or in other words, at a given frequency an aerial constructed in accordance with this invention can be made of smaller dimensions than a normal half-way dipole.

In the form of the invention illustrated in Figures 3 and 4, a singly folded dipole is used. Figures 6 and 7 show one way in which a doubly folded dipole may be produced in accordance with the invention. The conductor on the front surface of the support 14 is, as shown in Figure 6, of the same form as that in Figure 3. On the back surface of the support 14 are provided two conductors, one within the other and insulated from one another excepting at the ends G^1 and H^1. These ends G^1 and H^1 or other suitable points are connected by rivets or the like to the points G and H or other points respectively in Figure 6.

Another way in which multi-folded dipoles can be produced is by employing a plurality of supports, arranged in a stack and having a conductor on both outer surfaces of the stack and between each adjacent pair of supports. One example where the folding is double is shown in Figures 8, 9, 10 and 11. The structure comprises two insulating supports 14^1 and 14^{11}, the former having a conductor 15 of the shape shown in Figure 8 arranged on its upper surface and no conductor upon its lower surface. The supporting member 14^{11}, shown in Figure 9, has conductors 16 and 17 of the shape shown arranged upon its upper surface and thus in contact with the lower surface of the supporting member 14^1 and a conductor 18 as shown in Figure 10 upon its lower surface. Suitable points such as H and H^1 and G and G^1 are connected together respectively, while the ends P and Q are left unconnected.

The reactance between terminals E and F may be neutralised by suitably choosing the points to be connected together as already described with reference to Figures 3 and 4.

Having now particularly described and ascertained the nature of our said invention, and in what manner the same is to be performed, we declare that what we claim is:—

1. An aerial structure of the type set forth, wherein the conductors constituting the centre-fed dipole and the said further conductor or conductors are arranged on opposite sides of an insulating member and the conductors are in the form of thin strips of conducting material carried by the insulating member.

2. An aerial structure of the type set forth comprising three or more sets of conductors one of which constitutes the centre-fed dipole and the other sets constituting the said further conductors, and a plurality of insulating members arranged in a stack, two of the sets being disposed upon the two outer surfaces of the stack and the one or more other sets being disposed between adjacent insulating members.

3. A structure according to claim 1 or 2, wherein the insulating member or each such member is in the form of a flat plate having the conductors fixed upon the surfaces thereof.

4. A structure according to claim 1, 2 or 3, wherein connections between the conductors on opposite sides of the insulating member or members are made by means of rivets or the like passing through the said member.

5. An aerial structure of the type set forth, substantially as described with reference to, or as shown in, Figures 3 and 4, Figures 6 and 7, or Figures 8 to 11 of the drawings accompanying the provisional specification.

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Dated this 12th day of August, 1949.

REDDIE & GROSE,
Agents for the Applicants,
6, Bream's Buildings, London, E.C.4.

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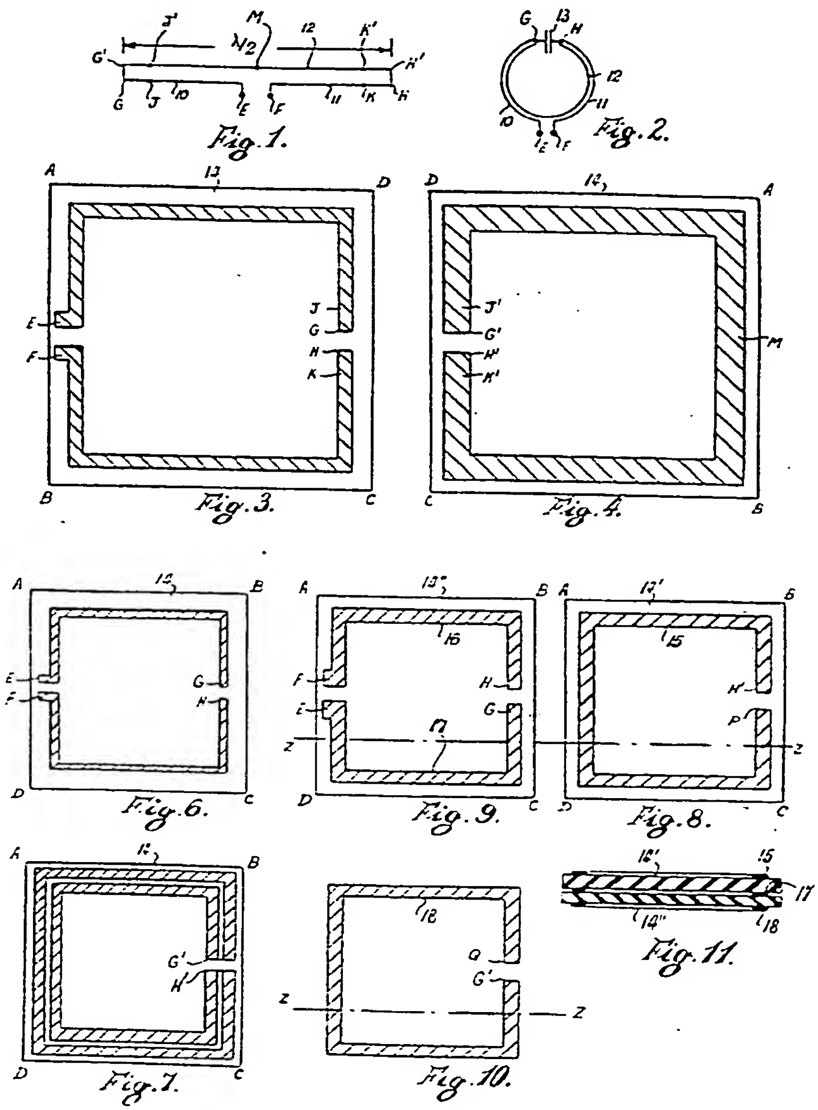
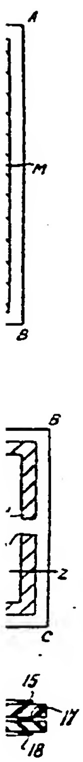


Fig.1. Fig.2. Fig.3. Fig.4. Fig.6. Fig.9. Fig.8. Fig.7. Fig.10. Fig.11.

[This Drawing is a reproduction of the Original on a reduced scale.]



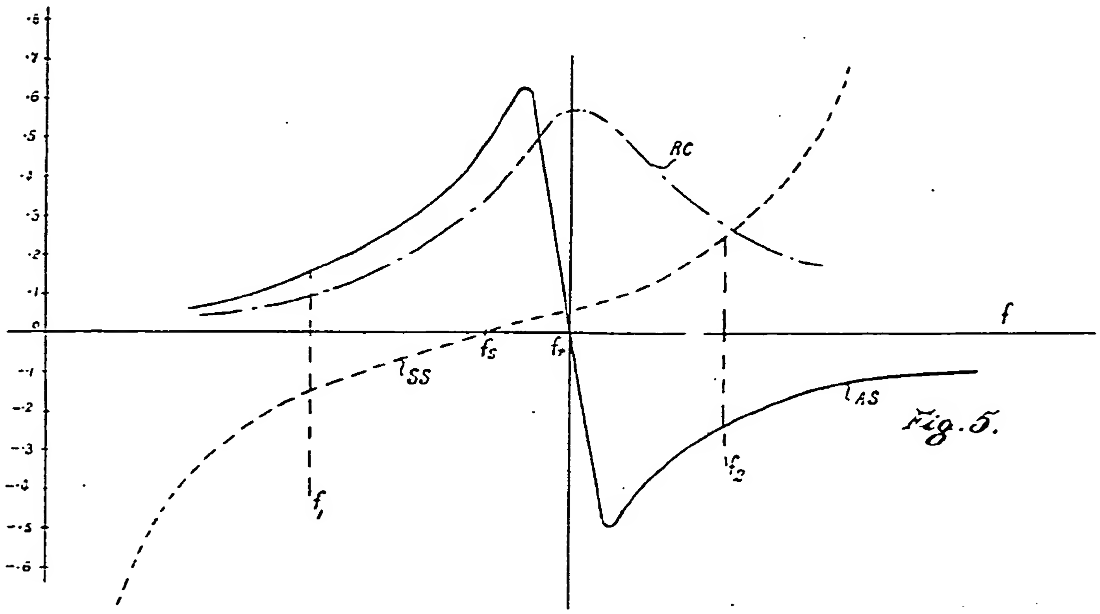


Fig. 5.

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652,716 PROVISIONAL SPECIFICATION

2 SHEETS

SHEET 1

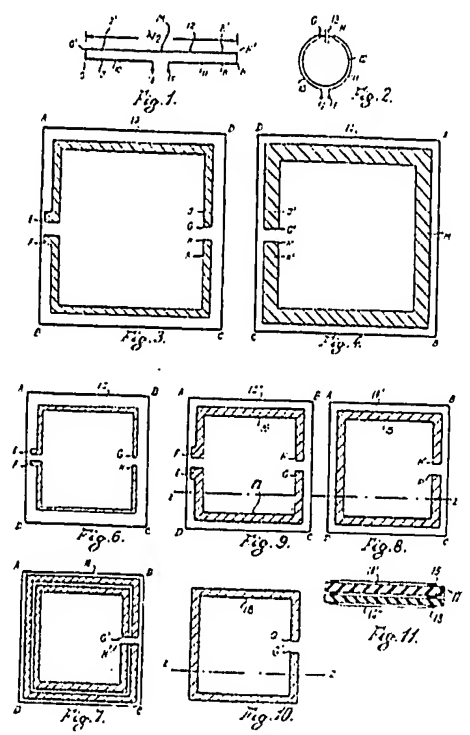

Fig.1. Fig.2. Fig.3. Fig.4. Fig.6. Fig.9. Fig.8. Fig.7. Fig.10. Fig.11.

SHEET 2

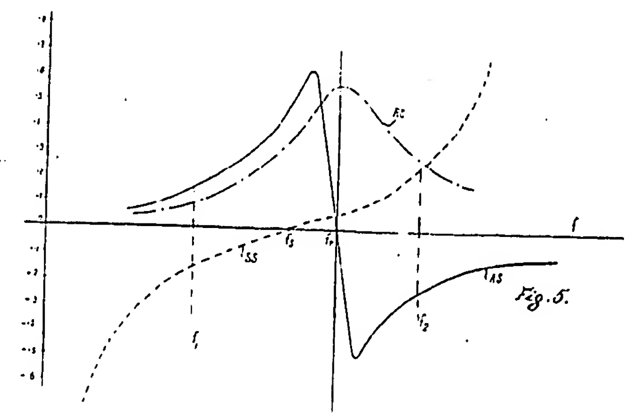

Fig.5.

(This Drawing is a reproduction of the Original on a reduced scale.)

H.M.S.O.(Ty.P.)

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